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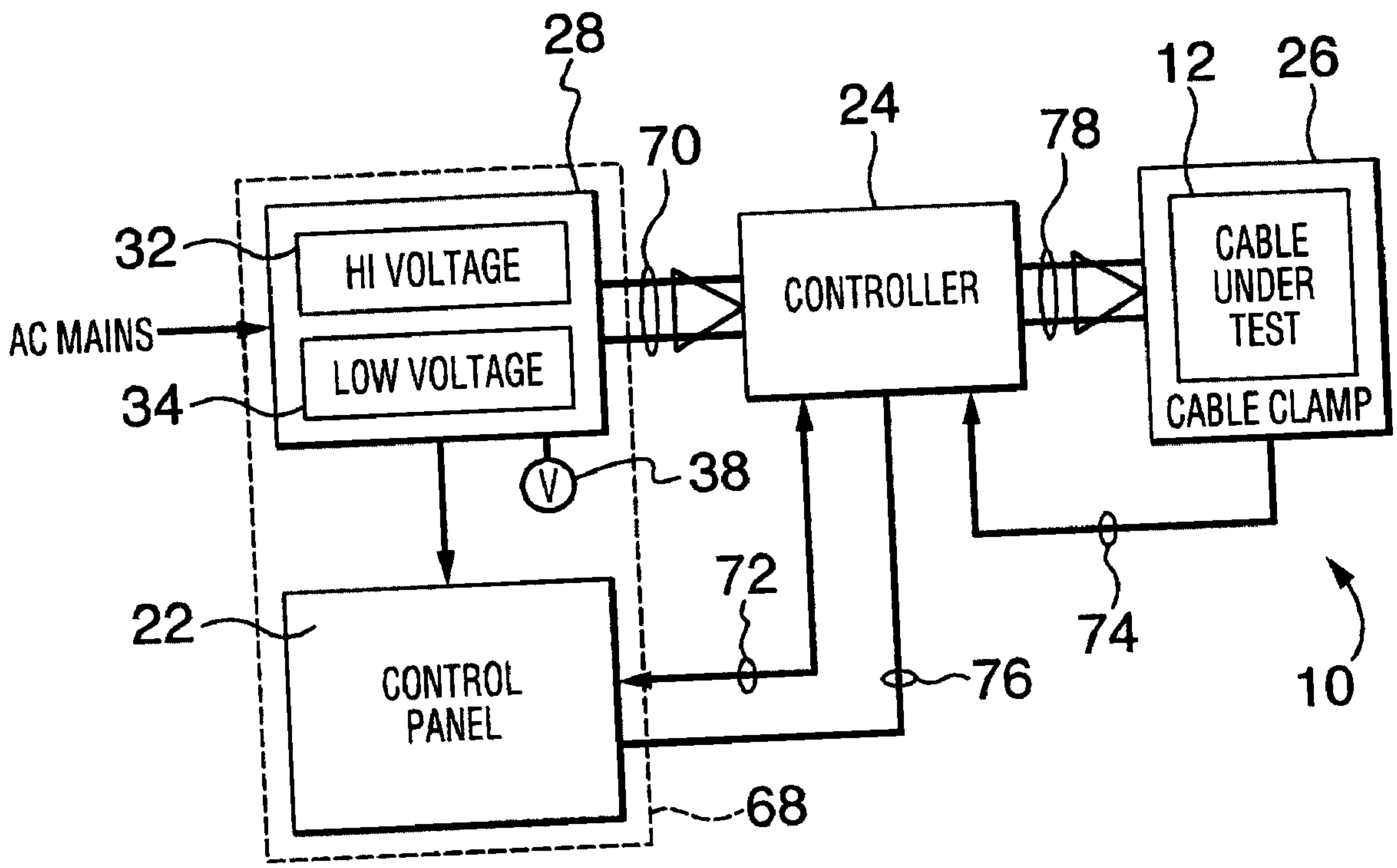

(57) Abrégé/Abstract:
Apparatus for product quality and safety testing of circuit size electrical cable having plural conductors is disclosed. The disclosed embodiments of the invention include simplified apparatus and method for testing both the conductivity and insulation integrity of such cable. A programmable logic controller including routines for controlling the test procedure organizes and regiments both the testing apparatus and the test procedures to ensure rapid and efficient electrical compliance with the test standards and provides maximum personnel safety.

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ABSTRACT OF THE INVENTION

Apparatus for product quality and safety testing of circuit size electrical cable having plural conductors is disclosed. The disclosed embodiments of the invention include simplified apparatus and method for testing both the conductivity and insulation integrity of such cable. A programmable logic controller including routines for controlling the test procedure organizes and regiments both the testing apparatus and the test procedures to ensure rapid and efficient electrical compliance with the test standards and provides maximum personnel safety.

AUTOMATIC TESTING OF CIRCUIT-SIZE CABLES

TECHNICAL FIELD

The present invention relates to product quality and safety testing of non-metallic (NM) and underground feeder (UF) circuit-size electrical cable having plural conductors. More particularly, the present invention relates to an apparatus and method for automatic testing of the continuity of the individual wires and of the insulation leakage integrity of such cable in packaged lengths primarily intended for retail sale. The automatic cable tester incorporates a programmable logic controller programmed to carry out the testing process in an efficient manner.

BACKGROUND ART

Various local and national governmental authorities have established standards that require certain electrical cables to undergo continuity and insulation leakage testing before sale to the public. When such standards require that each length of cable be tested individually, the procedure becomes highly labor-intensive and adds significantly to the product cost.

Previously, such cable was tested manually by first connecting the respective ends of the cable to a voltage source and a lamp or meter for indicating electrical continuity through individual wires comprising the cable. Thereafter, any electrical insulation leakage between the wires was tested by means of a megohmmeter or the like to indicate insulation faults or failure.

Because the procedure was time-consuming and tedious, only a limited number of lengths of cable could be tested per hour by any one person with such an apparatus. Moreover, if high voltages were involved, the testing personnel could be subjected to safety hazards if the cables were mishandled. The insulation leakage test frequently utilized voltage levels capable of inflicting serious or lethal injury.

DISCLOSURE OF INVENTION

In view of the foregoing limitations and shortcomings of the prior art testing methods and procedures, as well as other disadvantages not specifically mentioned above, it should be apparent that there exists a need in the art for an improved apparatus and method for testing circuit size electrical cables having multiple conductors.

More particularly, there exists a need for a testing system that automatically organizes and regiments both the testing apparatus and the test procedures to ensure rapid and efficient electrical compliance with the test standards and provides maximum personnel safety.

Since the operating and test voltage standards may vary according to different standards, the test voltage level must be adjustable to the desired values without dependence on the available input voltage level. The test voltage level or levels may require verification.

It is, therefore, a primary object of this invention to fulfill those needs by providing an automated cable tester which is programmed to carry out the testing routines on a cable. A programmable logic controller (PLC), provided with the test routines, is supplied with the high and low test voltages. The PLC serves as a means for selectively connecting the conductors to the test voltages and to the various indicators which signal the progress and success or failure of the cable under test. It communicates the test voltages and signals to the cable via relays under operator control from a control panel and provides signal indications of the test status via a plurality of lamp indicators located on the control panel. The programmable logic controller (PLC) contains routines for carrying out the continuity tests and/or the insulation integrity tests.

A feature of the invention is that once the cable is connected to the test apparatus, the programmable logic controller steps through each portion of each of the required tests according to a standard routine, giving pass/fail or trouble indicators at each step, as appropriate.

The invention includes routines for testing insulation leakage integrity and conductivity of each conductor in the cable at predetermined voltage levels.

Another feature of the invention is the inclusion of a setup switch coordinated with a cable identification routine to ensure that both two- and three-wire cables are fully and properly tested, with automatic detection/error alarm should the control switch be set incorrectly. The invention includes routines for determining the position of the two-three-wire switch, the status of the 2/3 wire indicator, and the wire connected for ensuring that two- and three-wire cables are properly tested. This fail-safe feature ensures that all conductors in a three-wire cable are tested for continuity and insulation leakage integrity, yet false readings of failed continuity are not given for two-wire cables due to the absence of the additional wire of a three-wire cable.

With the foregoing and other advantages and features of the invention that will become hereinafter apparent, the nature of the invention may be more clearly understood by reference to the following detailed description of the invention, the appended claims, and the various figures illustrated in the attached drawings.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a block diagram illustrating a preferred embodiment of the present invention and showing the relationships among the elements;

FIG. 2 is a fragmented diagrammatic view of a cable including multiple insulated wires, of the type to which the present invention is directed;

FIG. 3 is a layout view of a control panel suitable for the present invention;

FIGs. 4A through 4D comprise a flow chart diagram illustrating one embodiment of an automated cable testing procedure according to the main embodiment of the invention;

FIG. 5 is a block diagram of the programmable controller, illustrating the inputs and outputs of the present invention; and

FIGs. 6A through 6D comprise a schematic diagram of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

There is shown in FIG. 1 a block diagram schematically illustrating test apparatus constructed in accordance with the present invention and generally designated by the numeral 10. The apparatus 10 is suitable for automated testing of circuit size electrical cable 12 having plural conductors, or wires (see FIG. 2). Included in the apparatus 10 are a source of the test voltage levels desired, a control panel 22 from which an operator can control the test apparatus, a controller 24, and a clamp apparatus 26 for physically contacting and securing the cable 12 in place during the test.

As seen in FIG. 2, each cable is composed of at least two circuit conductors 16, 18, which are conventionally longitudinally encased within electrical insulation 30, and at least one ground wire 14, which is often uninsulated. This is a two-wire configuration, with ground. A third circuit conductor 20 may be included; when such is supplied, it is also usually insulated. This is a three-wire configuration, with ground. Occasionally, a cable may be encountered which does not include the ground wire 14. At least a portion of the ground wire may be wrapped with a paper wrapping (not shown).

The two specific electrical tests for which the automated test apparatus 10 and the related method of this invention are intended include continuity, here defined as the substantial electrical conductivity of the wire, and electrical insulation leakage, defined here to refer to an unacceptable electrical current path between a wire and one or more other wire conductors.

At least one source of voltage is required in the test apparatus 10. The present invention contemplates use of ordinary electrical AC voltages to provide separate continuity and insulation test voltages at about 24 volts (low voltage) and about 120 volts (high voltage) respectively, supplied from sources 32, 34. These voltage sources may be contained within a housing, such as housing 28, or they may be included in a common housing 68 with the control panel 22. However, appropriate DC voltages may be used with appropriate circuit equivalents and substitutes for the AC-specific elements described in the exemplary embodiment.

The test voltage level desired may be other than that conveniently available from the AC mains. In such situations, a means for adjusting the voltage to the required test levels may be provided to accommodate this voltage difference. A voltage meter may be used to measure the test voltages. In the present embodiment, the high voltage source 32 and the low voltage source 34 use one or more transformers to increase/decrease the testing voltage to the desired levels. The transformers are not shown here, selection thereof being within the routine skill of the person of ordinary skill in the art. The continuity test can be accommodated with a wide range of test voltage levels; however, the insulation leakage test must usually exceed a minimum voltage greater than the minimum which may be used for the continuity test. In such cases, an autotransformer or other variable transformer may be used to provide the higher insulation leakage integrity test voltage, as known to those skilled in the electrical testing arts. The present embodiment is shown in FIG. 1 in basic form, i.e., without the autotransformer, for simplicity.

To ensure that a minimum voltage level is achieved when a variable transformer is used, a voltage meter 38 may be included to indicate the actual test voltage. Separate meters can be used, one for each test voltage source, if desired, or only one meter 38 can be used and switched between the two sources.

Safety precautions commensurate with good engineering practice should be followed. A POWER ON switch 37 with a built-in indicator 36 is provided (to indicate when the test apparatus is energized, as potentially lethal voltage levels are anticipated) on control panel 22 (FIG. 3) and a fuse or other circuit overload protection device (see FIG. 6A) may be incorporated for this purpose into the power input circuit of the apparatus, as is known. Appropriate grounding of exposed metal cabinet parts should be arranged to minimize personnel safety hazards. It may also be convenient to include an emergency POWER OFF switch 40 (which may be a red mushroom type push button switch) in a prominent location on the front of control panel 22.

The present embodiment includes separate indicators for at least the continuity test and for the electrical leakage test; however, additional indicators can be usefully incorporated as explained hereinafter. Red and green indicators are generally used, respectively, to signal that the cable has failed a test or passed all of the tests. For the purposes of this illustrative example, individual red lamps 42, 44, and 46 (which may be incandescent-type lamps) are used to indicate failures or alarm status. Indicators 44, 46 signal the failure of a given cable to pass the respective insulation leakage or continuity leakage test. Indicators 48, 50 signal that a given cable has successfully passed the respective insulation leakage or continuity test.

Other indicators and other lamp colors may also be used. Amber and blue lamps are used to signal other than "pass" and "emergency" or "fail" conditions.

One useful feature of the present invention is a 2/3 wire test, in which the cable is tested automatically to determine if it includes two or three wires (plus ground, if used). When this test is included, a 2-WIRE/3-WIRE selector switch 52 may be used, with which the operator signals the apparatus whether a two-wire cable or three-wire cable is to be tested. A one- or two-color lamp can be used to indicate whether a two- or three-wire cable, matching the switch 52 position, is detected as present. Here, the separate amber VERIFY WIRE TEST SELECTOR POSITION and blue THREE-WIRE TEST indicators 54, 56 are used. A switch, which may be an alternate-action push button switch 58 can be used to reset the 2/3 wire circuit. Testing is then initiated, as described in greater detail hereinafter, by pressing a TESTING START push button switch 61 having a blue light 60. A red TESTING STOP push button switch 62 (which may be red for increased visibility) is provided to interrupt the test process.

A FAILURE RESET push button switch 64 is provided for resetting the process upon the occurrence of a fault condition attributable to a failed cable. Finally, when a given cable has passed all the relevant tests, a green QUALITY TEST PASSED indicator 66 can be illuminated to signal the successful completion of a particular series of tests.

Turning now to FIGs. 4A through 4D, there is shown a flow chart of an illustrative automatic test procedure for testing multiple conductor cable for both continuity and insulation integrity (leakage). In accordance with this procedure, the 2/3 wire check is performed first, followed by the insulation leakage test. However, the continuity or another test procedure could be performed after the 2/3 wire test. The 2/3 wire test need not be applied in those cases where only 2- or 3-wire cable products are contemplated. The procedure begins with START block 1000, wherein it is assumed that all pretesting procedures are completed, including system self-testing, initialization, reset, and the like.

At block 1010, the test procedure is begun by operating the START push button 61, or an equivalent action, which may also be accomplished automatically or manually. A brief test routine at INDICATOR ON block 1020 determines if the QUALITY TEST FAILURE indicator 42 is on. If so, the test procedure is terminated at STOP block 1030, or continued if not. At VERIFY WIRE SELECTOR block 1040 the VERIFY WIRE TEST SELECTOR POSITION indicator 54 is checked; if on, the test procedure is terminated at STOP block 1050, or continued if not.

In the next block 1060, NUMBER OF WIRES IN PRODUCT TO TEST, the number of wires in the cable undergoing test is determined, then verified in block 1080, at which step a test voltage (here given as 120 volts AC for this illustration) is applied to the output for wire "C" and wire "C" is monitored for the presence of a voltage at a level indicating a fault. If VOLTAGE DETECTED AT INPUT FOR "C" is true, that is, a voltage is detected at a fault level, the procedure steps to block 1100 and the operator is notified that the 2-WIRE/3-WIRE test selector switch 52 is possibly in the wrong position with an indicator, which may be an amber VERIFY WIRE TEST SELECTOR POSITION lamp 54. Otherwise, the procedure advances to block 1070 "A" INSULATION TEST where a test voltage (also given as 120 volts AC for this illustration) is applied to wire "A" and wires "B", "C", and "D" ("D" is arranged here as the ground wire 14) are monitored for a voltage level indicating a fault level.

If VOLTAGE DETECTED AT WIRE "B", "C", OR "D" at block 1110 is not true, the test procedure advances to "A" INSULATION TEST PASSED block 1120 and then to the "B" wire insulation test at block 1140. Otherwise, upon the affirmative presence of a fault voltage at block 1110 the test procedure steps to block 1130 "A" INSULATION TEST HAS FAILED and the program ordinarily steps to block 1260, to be subsequently described. Alternatively, the fault can be noted and the test procedure continued to block 1140.

Block 1140 involves testing the insulation of wire "B", at which step a test voltage (here given as 120 volts AC for illustration) is applied to the output for wire "B" and wires "A", "C", and "D" are monitored for the presence of a voltage at a level indicating a fault. If VOLTAGE DETECTED AT WIRE "A", "C", OR "D" at block 1150 is not true, the test procedure advances to "B" INSULATION TEST PASSED block 1170 and then to the "C" wire insulation test at block 1180. If VOLTAGE DETECTED AT WIRE "A", "C", or "D" is true at block 1150, that is, if a voltage is detected at a fault level, the procedure steps to block 1160 "B" INSULATION HAS FAILED and the program ordinarily steps to block 1260, to be subsequently described. Alternatively, the fault can be noted and the test procedure continued to block 1180.

Block 1180 involves testing the insulation of wire "C", at which step a test voltage is applied to wire "C" and wires "A", "B", and "D" are monitored for the presence of a voltage at a level indicating a fault. If VOLTAGE DETECTED AT WIRE "A", "B", OR "D" at block 1190 is not true, the test procedure advances to "C" INSULATION TEST PASSED block 1210 and then to the "D" wire insulation test at block 1220. If VOLTAGE DETECTED AT WIRE "A", "B", or "D" is true at block 1190, that is, if a voltage is detected at a fault level, the procedure steps to block 1200 "C" INSULATION HAS FAILED and the program ordinarily steps to block 1260, to be subsequently described. Alternatively, the fault can be noted and the test procedure continued to block 1220.

Block 1220 involves testing wire "D", at which step a test voltage is applied to wire "D" and wires "A", "B", and "C" are monitored for the presence of a voltage at a level indicating a fault. If VOLTAGE DETECTED AT WIRE "A", "B", OR "C" at block 1230 is not true, the test procedure advances to "D" INSULATION TEST PASSED block 1250 and then to the ALL INSULATION TESTS PASSED block 1280. <u>INSULATION TEST PASSED</u> indicator 48 is turned on. Note that the insulation among "A", "B", "C", and "D" is tested; if "D" is an uninsulated ground wire, the "D" insulation test merely tests for leakage between "D" and "A", "B", or "C".

If an INSULATION TEST HAS FAILED message is passed to block 1260 from one or more of blocks 1130, 1160, 1200, or 1240, the operator is signalled with <u>INSULATION TEST FAIL</u> indicator 44 at block 1260 and the <u>QUALITY TEST FAILED</u> indicator 42 signals the failure.

From PASSED ALL INSULATION TESTS block 1290, the program steps to the continuity tests. From a negative response to the ALL INSULATION TESTS PASSED block 1280, the program may alternatively be stepped to the continuity test portion of the program beginning at block 1300.

In the continuity tests described below, a low voltage is used to determine the continuity of the wires in the cable. For the purpose of this illustration, a low voltage level of 24 volts AC is used. Other voltage levels can be substituted. Either alternating- or direct current may be used. In the continuity test, the low voltage source 34 is connected to each end of the respective wires in the test cable and a favorable indication of continuity is given the operator when the test is passed.

Beginning with a first wire, here labeled wire "A", the test voltage is applied to block 1300 and detected at block 1310 if present; an affirmative indication is given at block 1330 to indicate continuity and the program steps to block 1340 for the next test. If no voltage is detected at block 1310, the "A" wire fails: "A" CONTINUITY TEST HAS FAILED, block 1320 and an indication of failure is passed to block 1480, described hereinafter. The testing process may also be continued at block 1340 in case of a failure.

The second wire, labeled wire "B", is similarly tested. The test voltage is applied at block 1340 and detected at block 1350 if present; an affirmative indication is given at block 1350 to indicate continuity and the program steps to block 1370 for the next test at 1380. If no voltage is detected at block 1350, the "B" wire fails: "B" CONTINUITY TEST HAS FAILED, block 1360, and an indication of failure is passed to block 1480, described hereinafter. The testing process may also be continued at block 1380 in case of a failure.

At block 1380, the NUMBER OF WIRES IN PRODUCT TO BE TESTED is ascertained by reference to the <u>2-WIRE/3-WIRE</u> selector (switch 52 position is detected) to determine if further conductors are present to be tested. If only two wires are to be tested, the program steps to block 1410.

If the cable includes three wires, then wire "C" is tested at block 1390. The test voltage is applied at block 1390 and detected at block 1400 if present; an affirmative indication is given at block 1410 to indicate continuity and the program steps to block 1440 for the next test. If no voltage is detected at block 1400, the "C" wire fails: "C" CONTINUITY TEST HAS FAILED, block 1420. Two reasons may cause this failure; the wire continuity may fail or the 2-wire/3-wire switch 52 may be in the wrong position, in which case the operator signal VERIFY WIRE TEST SELECTOR POSITION 54 is activated. An amber lamp indicator is preferred for this operator signal. If the 2-WIRE/3-WIRE switch 52 is correctly positioned, an indication of failure is passed to block 1480, described hereinafter.

Wire "D" here is tested in the same way. The test voltage is applied at block 1440 and detected at block 1450 if present; an affirmative indication is given at block 1500. If no voltage is detected at block 1450, the "D" wire fails: "D" CONTINUITY TEST HAS FAILED, block 1470 and an indication of failure is passed to block 1480. If A CONTINUITY TEST HAS FAILED message is passed to block 1480 from one or more of blocks 1320, 1360, 1420, 1470, the operator is signalled the occurrence of this fact with the CONTINUITY TEST FAILED indicator 46 at block 1480 and the QUALITY TEST FAILED indicator 42 signals the failure at block 1490.

From PASSED ALL CONTINUITY TESTS block 1500 the PASSED TEST CONTINUITY signal to indicator 50 is activated 1510, and the program steps to the ALL INSULATION AND CONTINUITY TESTS PASSED? block 1520. At this block, a negative result STOPs the process at block 1530, while an affirmative result is passed to block 1540 PRODUCT HAS PASSED ALL QUALITY TESTS and the operator is signalled of this result. A QUALITY TEST PASSED lamp indicator 66 may be used; applicants' apparatus includes a green lamp, which may be an incandescent lamp, for this purpose. This ends the test at block 1550.

FIG. 5 illustrates the programmable logic controller (PLC) 24 with its respective inputs and outputs. An Allen-Bradley Corp. Model 500 SLC Programmable Controller (or equivalent) may be used for this function. The PLC 24 receives a plurality of inputs, shown at the bottom of its block in FIG. 5, and produces a plurality of outputs, shown at the top of its block. Inputs include the input voltages 70, operator inputs 72, and PLC input readings 74 from the cable test circuit. Outputs include those for the test status indicators 76, discussed above, and the test voltage outputs 78, also discussed above.

At input voltages 70, the inputs include 120 volt AC power, and control of the test voltage sources via relays. The operator inputs at 72 include, for this example, connection to the TESTING START push button switch 61 and its light 60, the TESTING STOP push button switch 62, the emergency POWER OFF push button switch 40, the 2-WIRE/3-WIRE selector switch 52, the FAILURE RESET switch push button switch 64, and the VERIFY WIRE TEST SELECTOR POSITION RESET push button switch 58. Additional PLC inputs are available for additional features, as may be desired.

The input readings at 74 include, for this example, a plurality of 120 volt AC control power lines for inputs via relay contacts, with several available lines for expansion.

The test status indicator outputs at 76 include, for this example, a line to the indicator lamp portion 60 of the TESTING START push button switch 61 indicating a TESTING IN PROGRESS condition, a line to INSULATION TEST FAILED indicator 44, a line to INSULATION TEST PASSED indicator 48, a line to CONTINUITY TEST FAILED indicator 46, a line to CONTINUITY TEST PASSED indicator 50, a line to QUALITY TEST FAILED indicator 42, a line to QUALITY TEST PASSED indicator 66, and a line to VERIFY SELECTOR POSITION indicator 54.

The test voltage outputs at 78 to the cable 12 under test include, for this example, a 120 volt AC line to wire "A" for the insulation integrity test, a 120 volt AC line to wire "B" for the insulation integrity test, a 120 volt AC line to wire "C" for the insulation integrity test, and a 120 volt AC line to wire "D" for the insulation integrity test; and a 24 volt AC line to wire "A" for the continuity test, a 24 volt AC line to wire "B" for the continuity test, a 24 volt AC line to wire "C" for the continuity test, and a 24 volt AC line to wire "D" for the continuity test.

These connections are made directly to the wires, either through clip type connectors, or preferably, through a pair of clamps capable of making physical and electrical connection to the wires. The pair of cable clamp devices is identified generally by reference numeral 26 (see also FIG. 6B). The specific apparatus for making cable connections to the cable does not, however, form a part of the present invention.

A detailed schematic diagram for practicing a preferred embodiment of the present invention is shown in FIG. 6 which illustrates electrical details of the system. FIG. 6A illustrates the power supply and main control elements, including details of the high and low voltage power supplies 32, 34 and the AC mains power handling. AC mains power enters via a conventional power cable 400 and is supplied to a power transformer 402, which may be an isolation transformer. Fuse 401 provides protection in case of failure of the power transformer 402. One side of the transformer 402 secondary may be grounded, or "earthed", as may be required by local electrical codes. Fuse 406 generally protects the entire secondary power transformer circuit, which secondary circuit also provides input power to the low voltage circuit 34. Using, for this example, nominal 120 volt AC mains at 400, the high voltage supply 32 can provide nominal 120 volt AC power to the PLC 26 at 203 with a simple isolation transformer, and nominal 120 volt AC control power to the test inputs and outputs at 206, described hereinafter. The ground, or neutral, return is available at N. Power is initially applied by pressing POWER ON switch 37, completing a current path via normally-closed POWER OFF emergency switch 40 and energizing control power relay 404 and POWER ON indicator 36. The relay contacts 451, 452 close on actuation of power relay 404 and the apparatus remains powered until POWER OFF switch 40 is pressed, breaking the current path. Control power is also applied to the primary of continuity test voltage transformer 405 via fuse 403 to provide the low voltage 24 volt AC continuity test voltage at 602.

The test clamping fixture 26 is illustrated in FIG. 6B, including a pair of cable clamping devices 441, 442 which make the physical and electrical connections to the cable 12 under test. Relays 408, 409, 410, and 411 control application of insulation test voltages to the conductors 16, 18, 20, and 14, respectively. These conductors are also identified herein as conductors "A", "B", "C", and "D", respectively. Relays 428, 429, 430, and 431 control application of the continuity test voltages to the conductors 16, 18, 20, and 14, respectively. Relay contact pairs 453, 454; 455, 456; 457, 458; and 459, 460 are used alternately in the continuity and insulation leakage tests.

Relays 408, 409, 410, and 411 are connected to the PLC at 308, 309, 310, and 311, respectively (see FIG. 6D). The relay common lines are returned to neutral via line N. Continuity relays 428, 429, 430, and 431 are connected between 508, 509, 510, and 511, respectively, and neutral at N as required during the continuity testing of the individual conductors 16, 18, 20, and 14, respectively. Collectively, lines 308, 309, 310, 311, 312, 313, 314, and 315 form the test voltage output lines 78, discussed above.

The test status indicator outputs 76, operator inputs 72, and power connections 70 are shown with respect to the PLC 24 in FIG. 6C. Indicators 42, 44, 46, 48, 50, 54, 60, and 66 have been discussed previously; they are connected to certain PLC 24 outputs and neutral at N. These outputs are, of course, related to the PLC 24 inputs and the programming of the PLC, as discussed previously. Certain operator inputs, consisting primarily of operator selected switch inputs at the control panel 22, are provided the PLC 24 through a group of input lines 72. These switches include the <u>2-WIRE/3-WIRE</u> selector switch 52, <u>VERIFY SELECTOR</u> switch 58, <u>START</u> switch 61, <u>STOP</u> switch 62, and <u>FAILURE RESET</u> switch 64. One end of each switch is connected to neutral at N; the remaining end is connected to a PLC 24 input. Three power inputs are provided the PLC 24 via cable 70: neutral at N, a ground connection (GND) and the 120 volt AC PLC power at 203, previously identified.

The remaining PLC inputs and outputs are shown in FIG. 6D, including input lines 74 and output lines 78. The input lines are isolated by relay contacts 461, 462, 463, 464, 465, 466, 467, and 468 to avoid improper voltage levels. Lines 206 are connected to 120 volt AC control power previously described. Outputs 508, 509, 510, and 511 are connected to relay connections previously described for FIG. 6B. Lines 308, 309, 310, and 311 bearing 120 volt AC for the insulation test are connected to the insulation test relays as previously described, while lines 312, 313, 314, and 315 bearing 24 volt AC are connected to the relays for the continuity test.

Although certain presently preferred embodiments of the invention have been described herein, it will be apparent to those skilled in the art to which the invention pertains that variations and modifications of the described embodiment may be made without departing from the spirit and scope of the invention. Accordingly, it is intended that the invention be limited only to the extent required by the appended claims and the applicable rules of law.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A method of automatically testing circuit size electrical cable having plural conductors individually connected to a test apparatus, comprising the steps of:

(a) distinguishing the connection of two- and three-wire cables to said test apparatus;

(b) providing an electrical insulation leakage test voltage;

(c) providing said test apparatus with a programmable logic controller having stored therein a routine defining a sequence of connection of said plural conductors to the electrical insulation leakage test voltage;

(d) operating said programmable logic controller in accordance with said routine stored therein to connect said plural conductors to the electrical insulation leakage test voltage in said sequence defined by said routine;

(e) automatically testing the electrical insulation leakage of each respective one of said plural conductors in said sequence of connection defined by said routine; and

(f) indicating either

(i) the occurrence of an electrical insulation leakage failure among the conductors, or

(ii) the successful completion of the electrical insulation leakage tests.

2. The test method of claim 1, wherein said test apparatus includes means for providing an adjustable continuity test voltage level, further including the step of adjusting the continuity test voltage level.

3. The test method of claim 1, wherein said test apparatus includes means for providing an adjustable continuity test voltage level and a means for indicating the

continuity test voltage level and a means for indicating the continuity test voltage level, further including the step of adjusting the continuity test voltage level to a predetermined continuity test voltage level indicated by said continuity test voltage level indicating means.

4. The test method of claim 1, wherein said test apparatus includes means for providing an adjustable electrical insulation leakage test voltage level, further including the step of adjusting the electrical insulation leakage test voltage level.

5. The test method of claim 1, wherein said test apparatus includes means for providing an adjustable electrical insulation leakage test voltage level and a means for indicating the electrical insulation leakage test voltage level, further including the step of adjusting the electrical insulation leakage test voltage level to a predetermined voltage level indicated by said electrical insulation test voltage level indicating means.

6. An apparatus for automated testing of circuit size electrical cable having plural conductors, comprising:

(a) a low voltage source;

(b) a test voltage source;

(c) cable clamp means to couple to a first end and a second end of each individual conductor of a cable under test;

(d) a plurality of low voltage operable isolation relays, each operable to interconnect said test voltage source to the first end of a corresponding individual conductor of the cable under test in said cable clamp means in response to a control signal;

(e) programmable logic control means to produce a sequence of low voltage control signals including a control signal for each said isolation relay in accordance with at least one stored test routine;

(f) a plurality of voltage sensor leads, each voltage sensor lead adapted to interconnect to a corresponding second end of each individual conductor of the cable under test in said cable clamp means to said programmable logic control means

(g) testing start means connecting to said control means operable to commence a predetermined stored test routine;

(h) testing stop means connecting to said control means operable to cease application of said testing voltage to said cable under test; and

(i) test result indicator means coupled to said programmable logic control;

whereby user operation of said testing start means will activate said programmable logic controller to perform a predetermined test routine the outcome of which will be indicated on said test result indicator, the said test being user interruptible at any time by operation of said testing stop means.

7. The test apparatus of claim 6 wherein said programmable logic controller includes at least one stored test routine to conduct a count of the conductors or a cable under test, further comprising:

(a) conductor count selection means connecting to said programmable logic control means;

(b) conductor count verification test activation means connecting to said programmable logic control means; and

(c) a conductor count verification test result indicator coupled to said programmable logic controller;

whereby user selection of a conductor count using the conductor count selection means followed by operation of said conductor count verification test activation means will produce a result on said conductor count verification test result indicator.

8. The test apparatus of claim 7 wherein said conductor count verification test result indicator comprises a light activated on successful completion of said conductor count verification test.

9. The test apparatus of claim 6 or 7 further including means to adjust the test voltage produced by said test voltage source.

10. The test apparatus of claim 8 wherein said means to adjust the test voltage produced by said test voltage source comprises an autotransformer.

11. The test apparatus of claim 6 wherein said testing stop means comprises a mushroom switch.

12. The test apparatus of claim 6 wherein said testing stop means is prominently oriented on the front panel of the test apparatus.

13. The test apparatus of claims 11 or 12 wherein said testing stop means is coloured red.

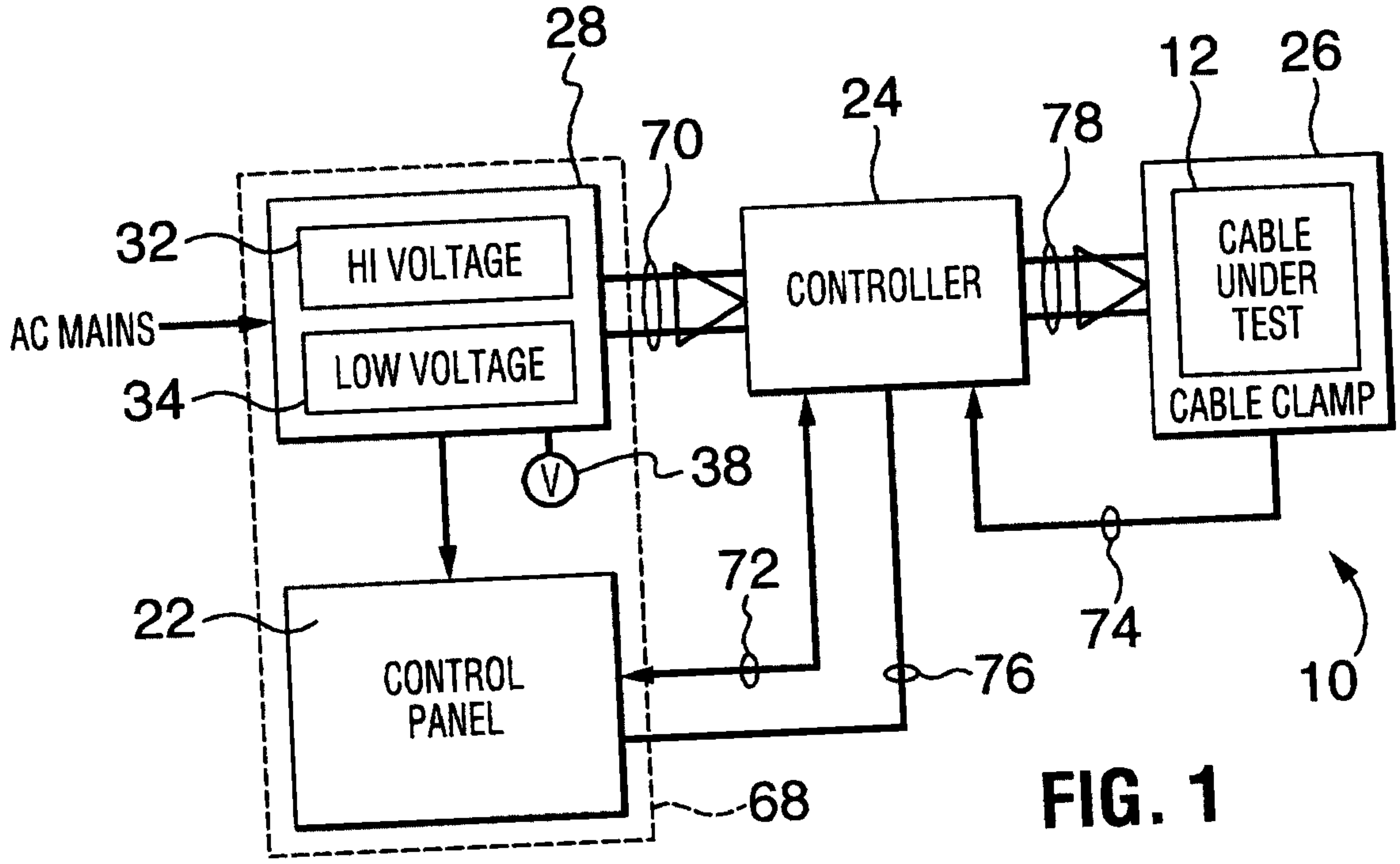

28
70
24
78
12
26
32
HI VOLTAGE
CONTROLLER
CABLE
UNDER
TEST
AC MAINS
LOW VOLTAGE
34
CABLE CLAMP
38
72
74
22
CONTROL
PANEL
76
10
68

FIG. 1

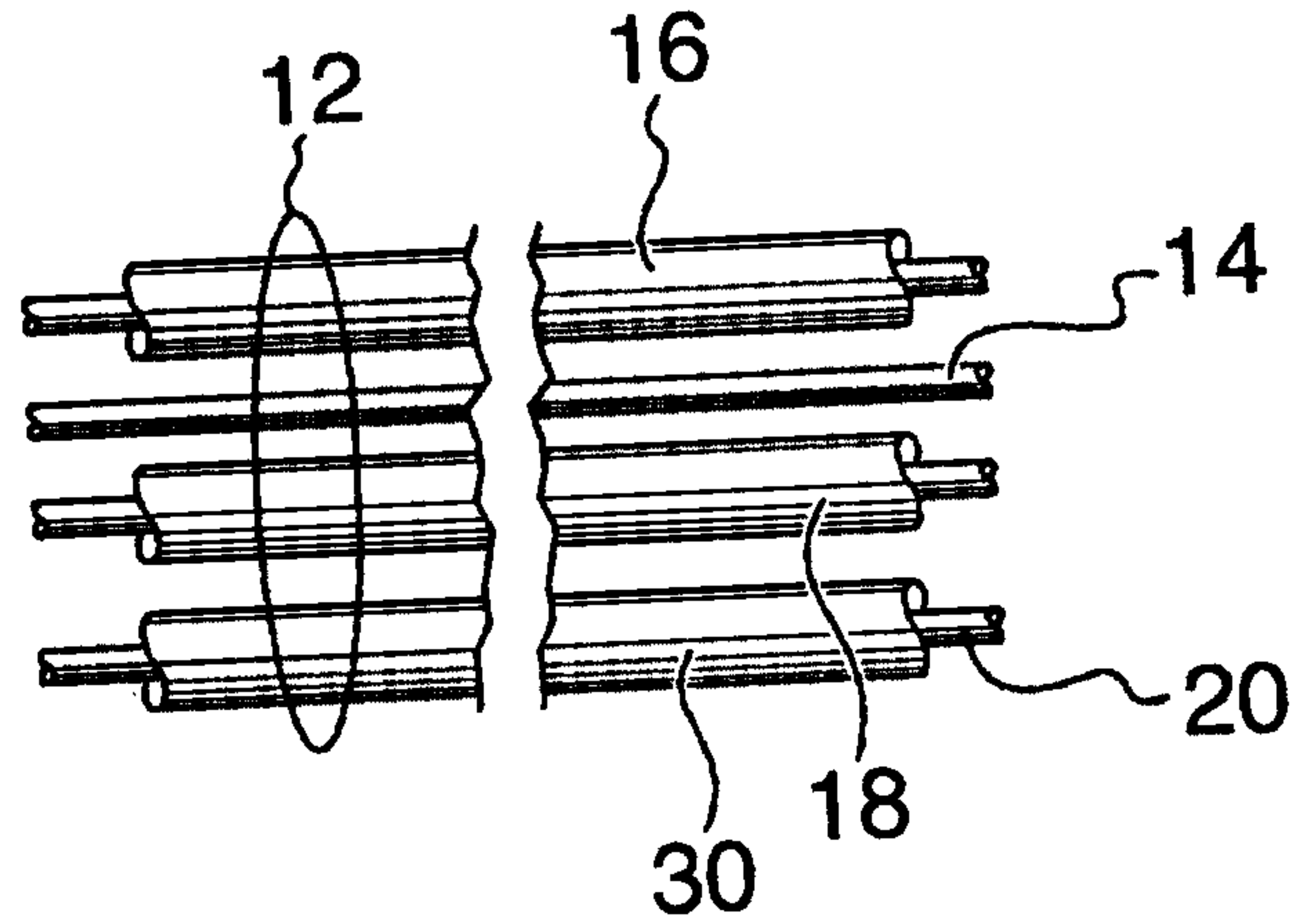

12
16
14
20
18
30

FIG. 2

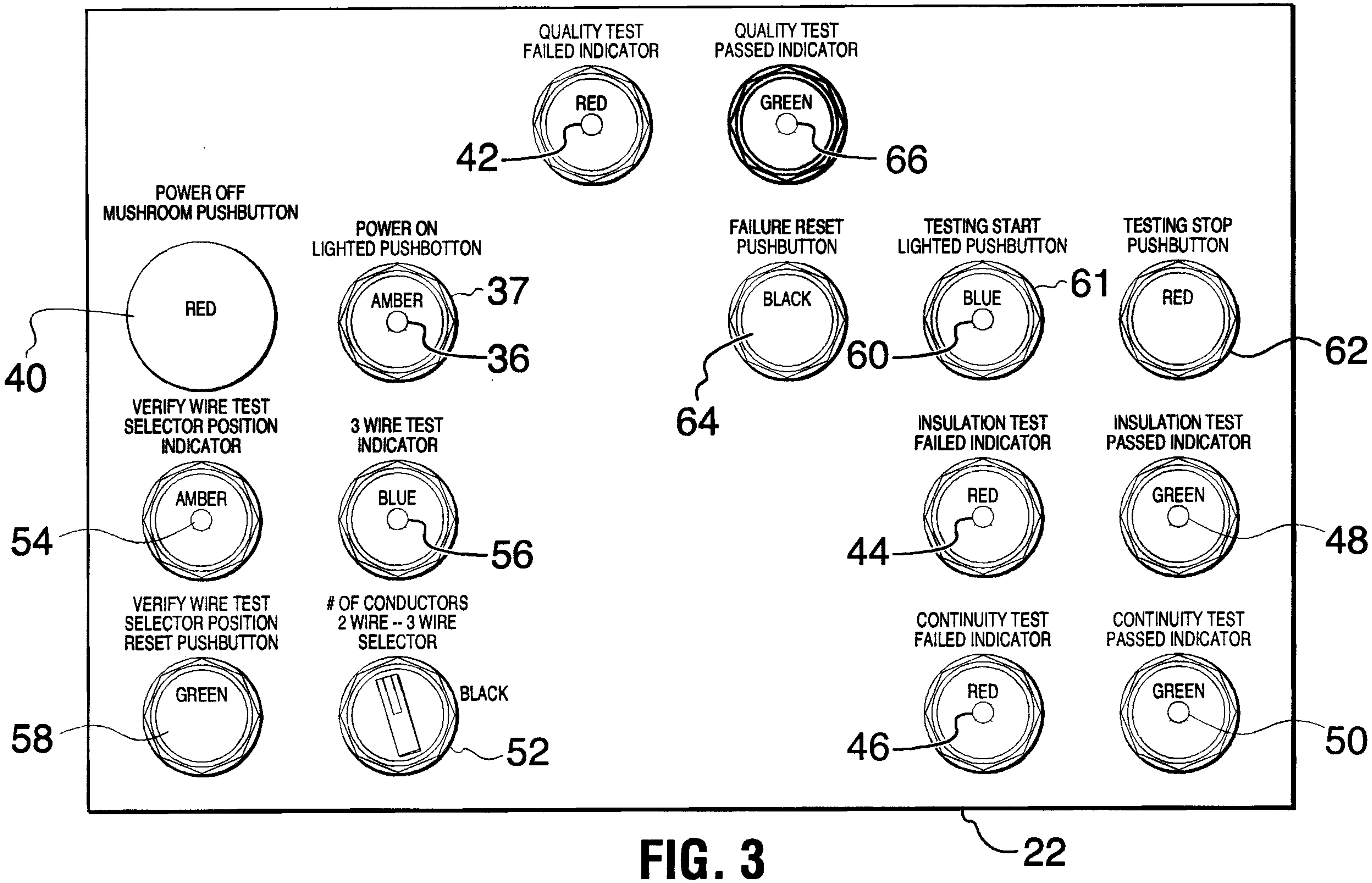

QUALITY TEST FAILED INDICATOR
RED
42
QUALITY TEST PASSED INDICATOR
GREEN
66
POWER OFF MUSHROOM PUSHBUTTON
RED
40
POWER ON LIGHTED PUSHBOTTON
AMBER
37
36
FAILURE RESET PUSHBUTTON
BLACK
64
TESTING START LIGHTED PUSHBUTTON
BLUE
61
60
TESTING STOP PUSHBUTTON
RED
62
VERIFY WIRE TEST SELECTOR POSITION INDICATOR
AMBER
54
3 WIRE TEST INDICATOR
BLUE
56
INSULATION TEST FAILED INDICATOR
RED
44
INSULATION TEST PASSED INDICATOR
GREEN
48
VERIFY WIRE TEST SELECTOR POSITION RESET PUSHBUTTON
GREEN
58
OF CONDUCTORS 2 WIRE -- 3 WIRE SELECTOR
BLACK
52
CONTINUITY TEST FAILED INDICATOR
RED
46
CONTINUITY TEST PASSED INDICATOR
GREEN
50
22

FIG. 3

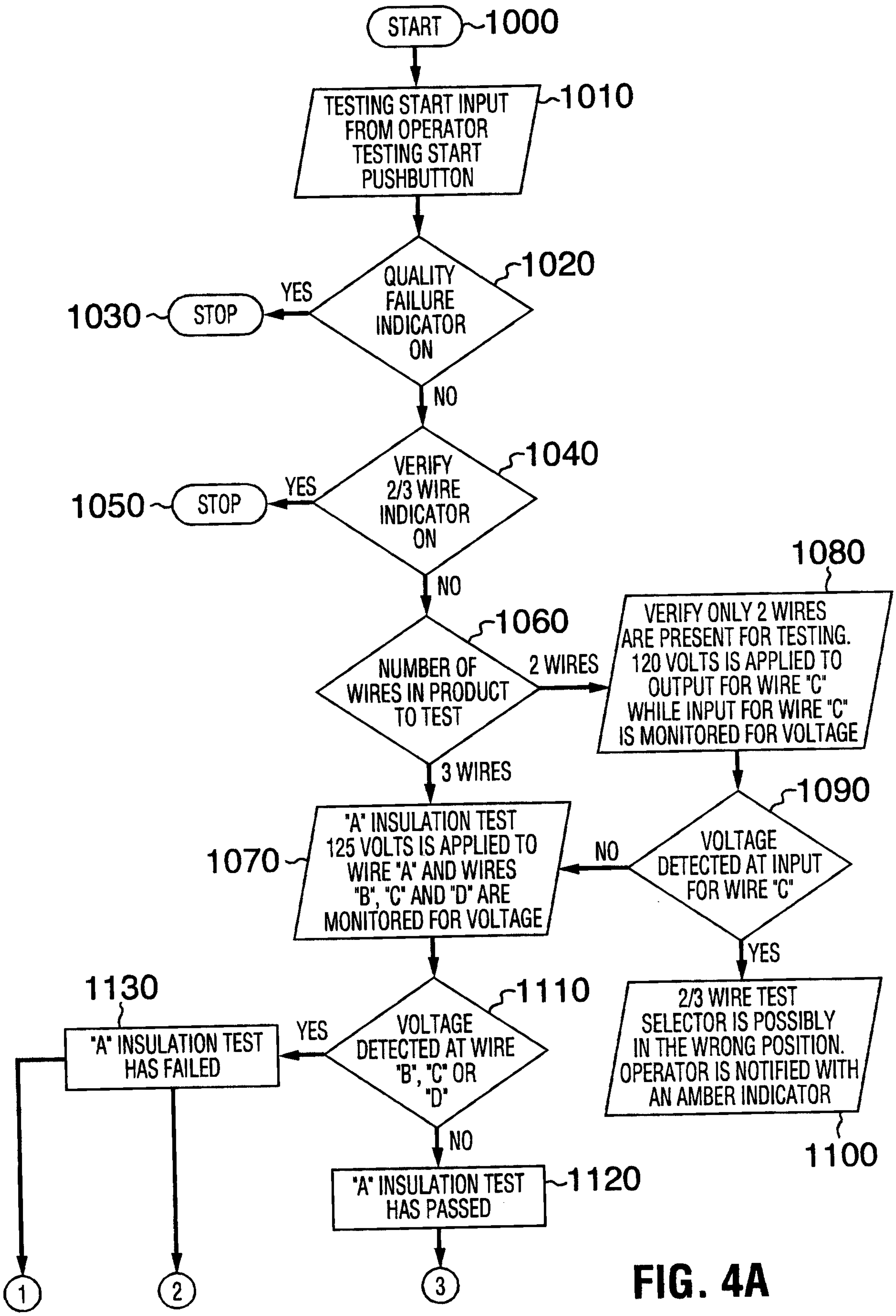

START
1000
TESTING START INPUT FROM OPERATOR TESTING START PUSHBUTTON
1010
QUALITY FAILURE INDICATOR ON
1020
YES
1030
STOP
NO
VERIFY 2/3 WIRE INDICATOR ON
1040
YES
1050
STOP
NO
NUMBER OF WIRES IN PRODUCT TO TEST
1060
2 WIRES
1080
VERIFY ONLY 2 WIRES ARE PRESENT FOR TESTING. 120 VOLTS IS APPLIED TO OUTPUT FOR WIRE "C" WHILE INPUT FOR WIRE "C" IS MONITORED FOR VOLTAGE
3 WIRES
"A" INSULATION TEST 125 VOLTS IS APPLIED TO WIRE "A" AND WIRES "B", "C" AND "D" ARE MONITORED FOR VOLTAGE
1070
VOLTAGE DETECTED AT INPUT FOR WIRE "C"
1090
NO
YES
2/3 WIRE TEST SELECTOR IS POSSIBLY IN THE WRONG POSITION. OPERATOR IS NOTIFIED WITH AN AMBER INDICATOR
1100
VOLTAGE DETECTED AT WIRE "B", "C" OR "D"
1110
YES
1130
"A" INSULATION TEST HAS FAILED
NO
"A" INSULATION TEST HAS PASSED
1120
1
2
3

FIG. 4A

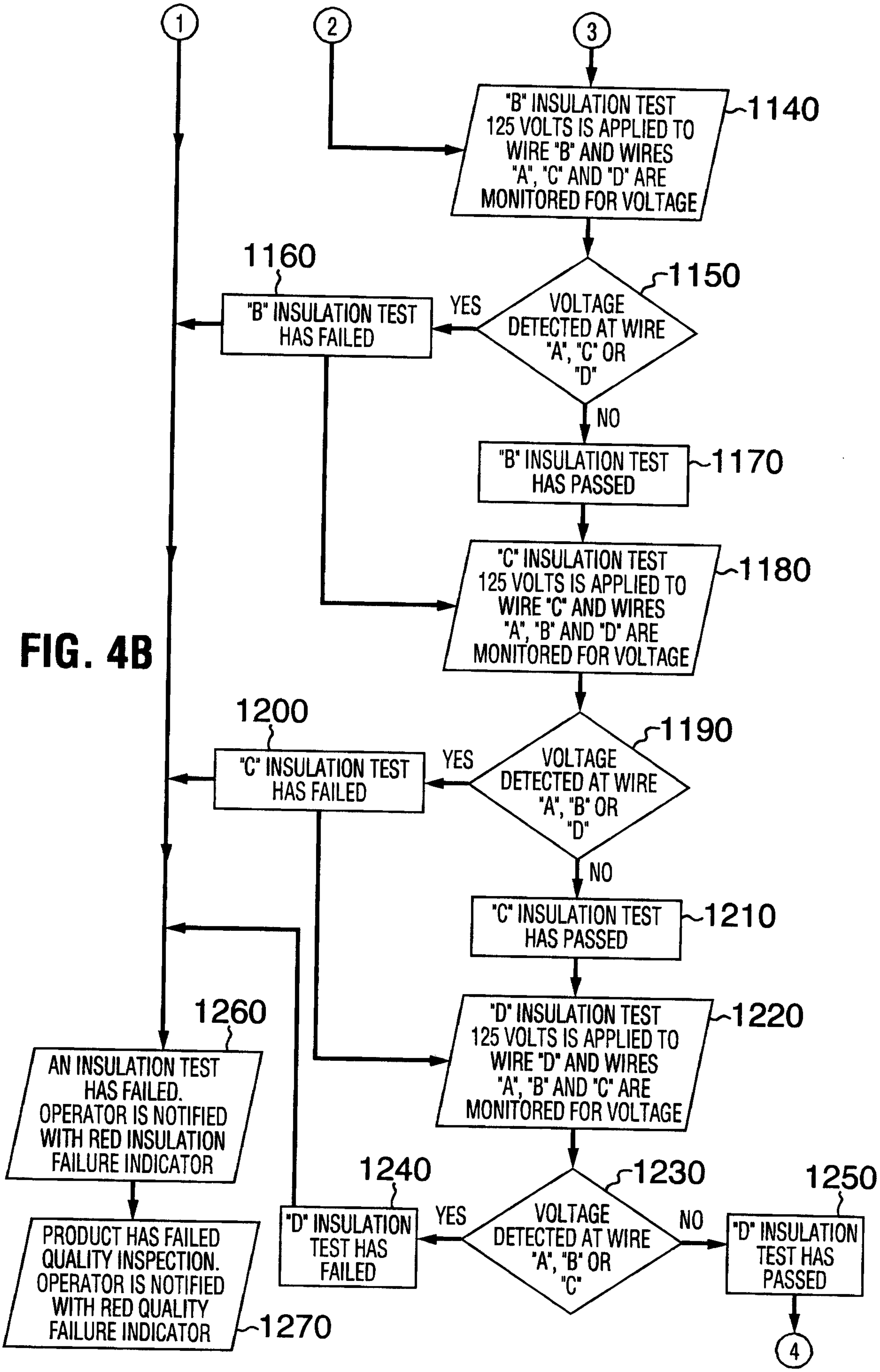

1
2
3
"B" INSULATION TEST 125 VOLTS IS APPLIED TO WIRE "B" AND WIRES "A", "C" AND "D" ARE MONITORED FOR VOLTAGE
1140
1160
"B" INSULATION TEST HAS FAILED
YES
VOLTAGE DETECTED AT WIRE "A", "C" OR "D"
1150
NO
"B" INSULATION TEST HAS PASSED
1170
"C" INSULATION TEST 125 VOLTS IS APPLIED TO WIRE "C" AND WIRES "A", "B" AND "D" ARE MONITORED FOR VOLTAGE
1180
1200
"C" INSULATION TEST HAS FAILED
YES
VOLTAGE DETECTED AT WIRE "A", "B" OR "D"
1190
NO
"C" INSULATION TEST HAS PASSED
1210
1260
"D" INSULATION TEST 125 VOLTS IS APPLIED TO WIRE "D" AND WIRES "A", "B" AND "C" ARE MONITORED FOR VOLTAGE
1220
AN INSULATION TEST HAS FAILED. OPERATOR IS NOTIFIED WITH RED INSULATION FAILURE INDICATOR
1240
1230
1250
"D" INSULATION TEST HAS FAILED
YES
VOLTAGE DETECTED AT WIRE "A", "B" OR "C"
NO
"D" INSULATION TEST HAS PASSED
PRODUCT HAS FAILED QUALITY INSPECTION. OPERATOR IS NOTIFIED WITH RED QUALITY FAILURE INDICATOR
1270
4

FIG. 4B

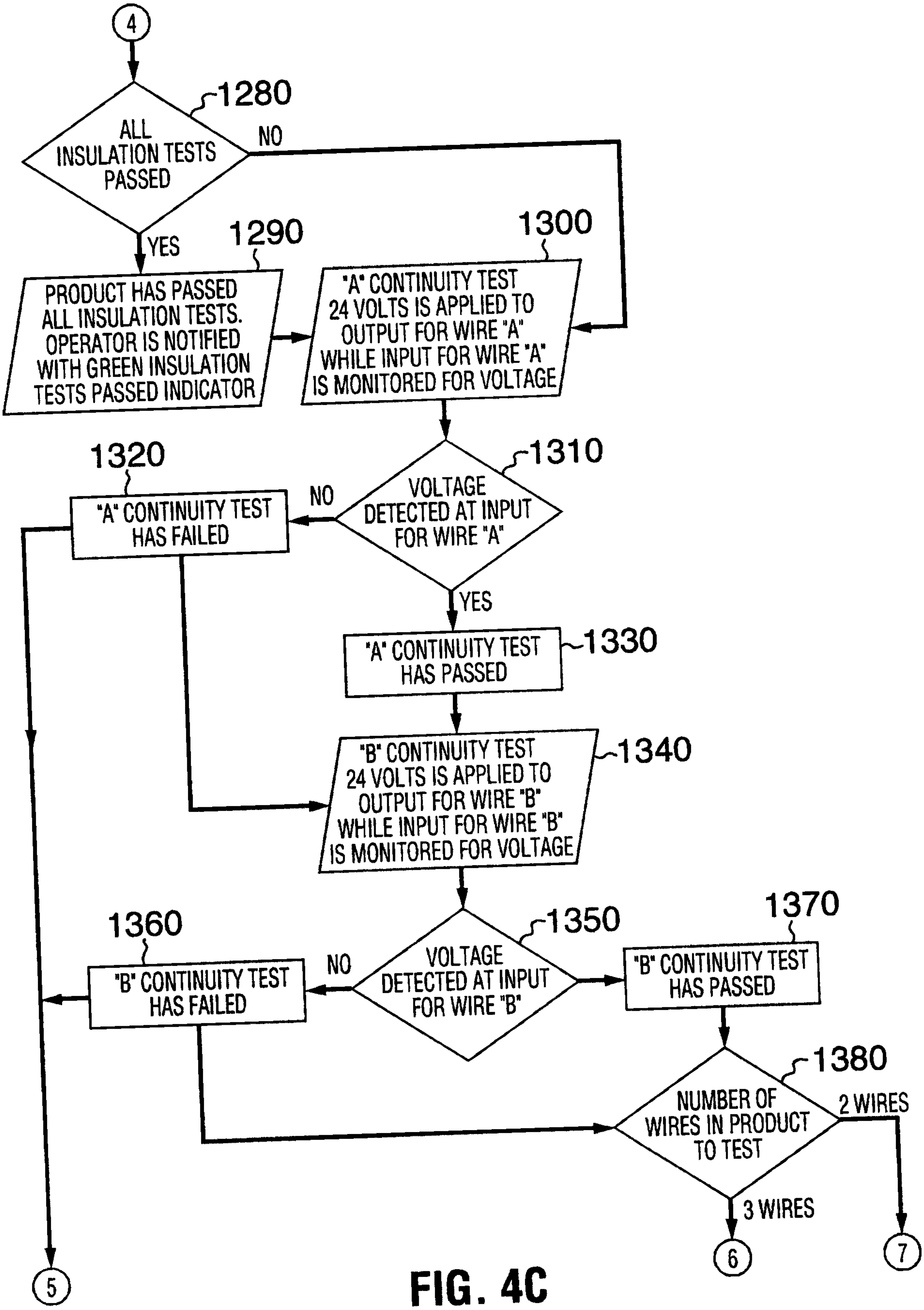

4
1280
ALL INSULATION TESTS PASSED
NO
YES
1290
PRODUCT HAS PASSED ALL INSULATION TESTS. OPERATOR IS NOTIFIED WITH GREEN INSULATION TESTS PASSED INDICATOR
1300
"A" CONTINUITY TEST 24 VOLTS IS APPLIED TO OUTPUT FOR WIRE "A" WHILE INPUT FOR WIRE "A" IS MONITORED FOR VOLTAGE
1320
"A" CONTINUITY TEST HAS FAILED
NO
1310
VOLTAGE DETECTED AT INPUT FOR WIRE "A"
YES
"A" CONTINUITY TEST HAS PASSED
1330
"B" CONTINUITY TEST 24 VOLTS IS APPLIED TO OUTPUT FOR WIRE "B" WHILE INPUT FOR WIRE "B" IS MONITORED FOR VOLTAGE
1340
1360
"B" CONTINUITY TEST HAS FAILED
NO
1350
VOLTAGE DETECTED AT INPUT FOR WIRE "B"
1370
"B" CONTINUITY TEST HAS PASSED
1380
NUMBER OF WIRES IN PRODUCT TO TEST
2 WIRES
3 WIRES
6
7
5

FIG. 4C

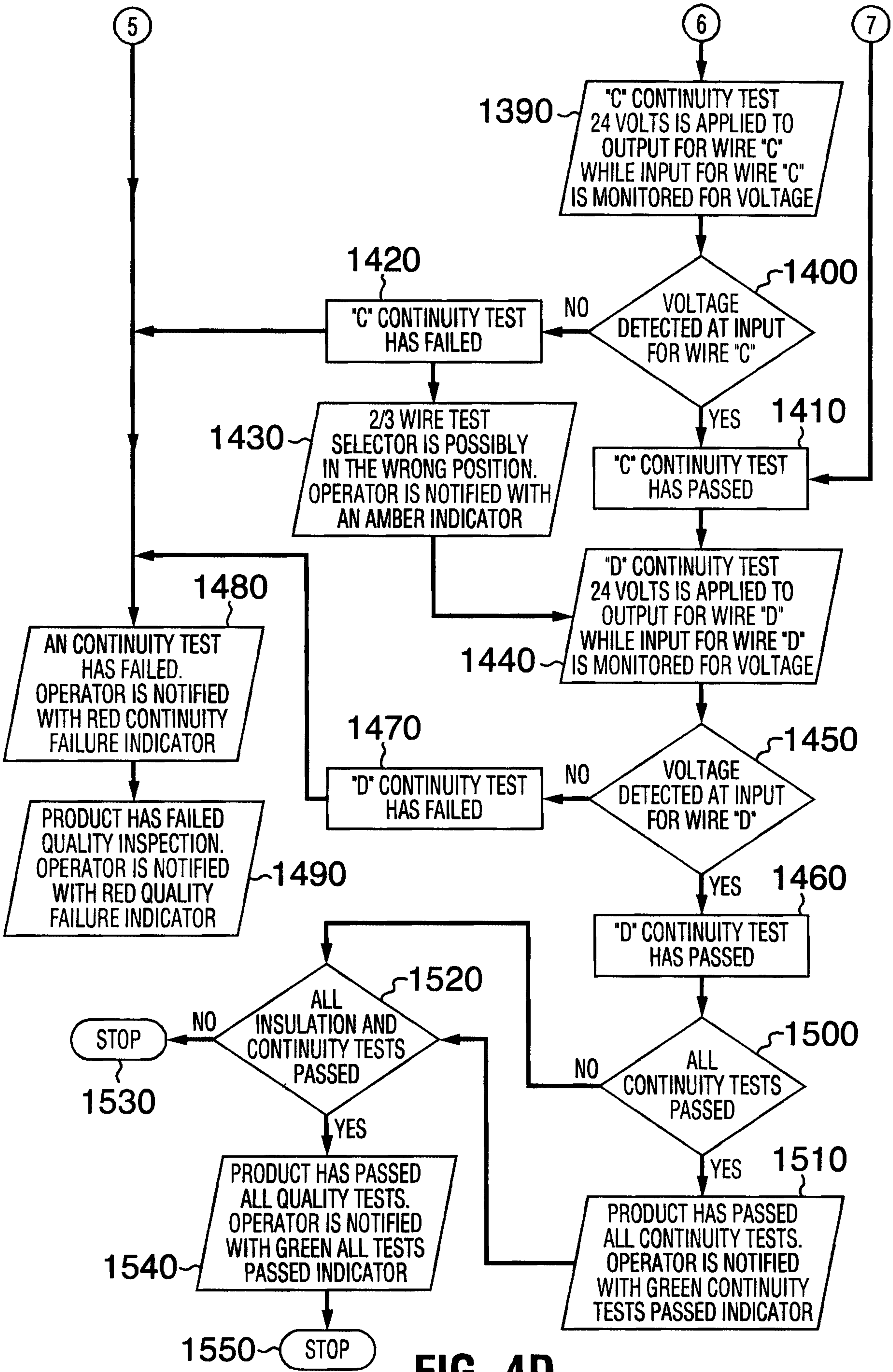

5
6
7
1390
"C" CONTINUITY TEST 24 VOLTS IS APPLIED TO OUTPUT FOR WIRE "C" WHILE INPUT FOR WIRE "C" IS MONITORED FOR VOLTAGE
1400
VOLTAGE DETECTED AT INPUT FOR WIRE "C"
NO
1420
"C" CONTINUITY TEST HAS FAILED
YES
1410
"C" CONTINUITY TEST HAS PASSED
1430
2/3 WIRE TEST SELECTOR IS POSSIBLY IN THE WRONG POSITION. OPERATOR IS NOTIFIED WITH AN AMBER INDICATOR
1440
"D" CONTINUITY TEST 24 VOLTS IS APPLIED TO OUTPUT FOR WIRE "D" WHILE INPUT FOR WIRE "D" IS MONITORED FOR VOLTAGE
1480
AN CONTINUITY TEST HAS FAILED. OPERATOR IS NOTIFIED WITH RED CONTINUITY FAILURE INDICATOR
1450
VOLTAGE DETECTED AT INPUT FOR WIRE "D"
NO
1470
"D" CONTINUITY TEST HAS FAILED
1490
PRODUCT HAS FAILED QUALITY INSPECTION. OPERATOR IS NOTIFIED WITH RED QUALITY FAILURE INDICATOR
YES
1460
"D" CONTINUITY TEST HAS PASSED
1520
ALL INSULATION AND CONTINUITY TESTS PASSED
NO
STOP
1530
1500
ALL CONTINUITY TESTS PASSED
NO
YES
YES
1510
PRODUCT HAS PASSED ALL CONTINUITY TESTS. OPERATOR IS NOTIFIED WITH GREEN CONTINUITY TESTS PASSED INDICATOR
1540
PRODUCT HAS PASSED ALL QUALITY TESTS. OPERATOR IS NOTIFIED WITH GREEN ALL TESTS PASSED INDICATOR
1550
STOP

FIG. 4D

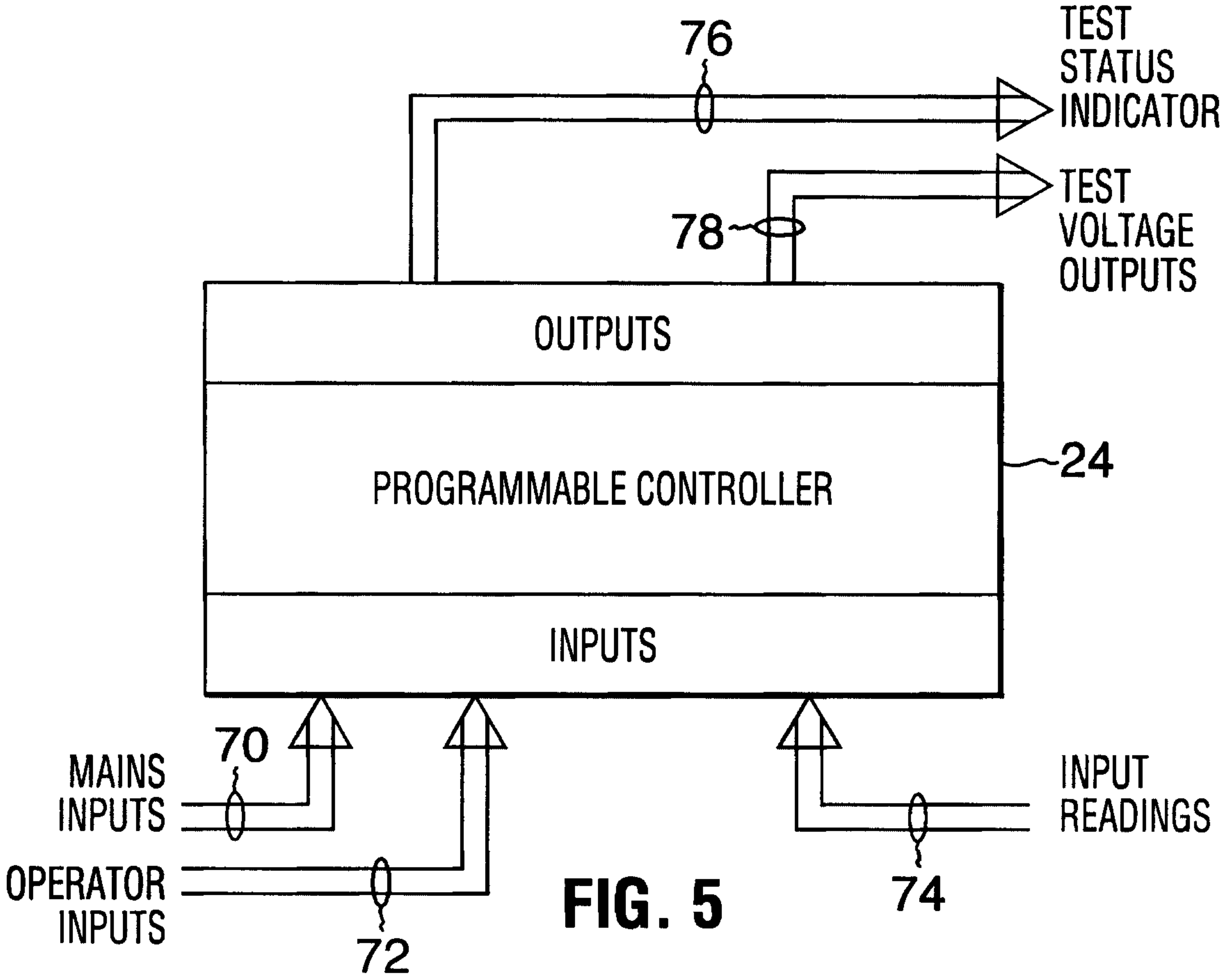

76
TEST
STATUS
INDICATOR
TEST
VOLTAGE
OUTPUTS
78
OUTPUTS
PROGRAMMABLE CONTROLLER
24
INPUTS
70
MAINS
INPUTS
OPERATOR
INPUTS
72
INPUT
READINGS
74

FIG. 5

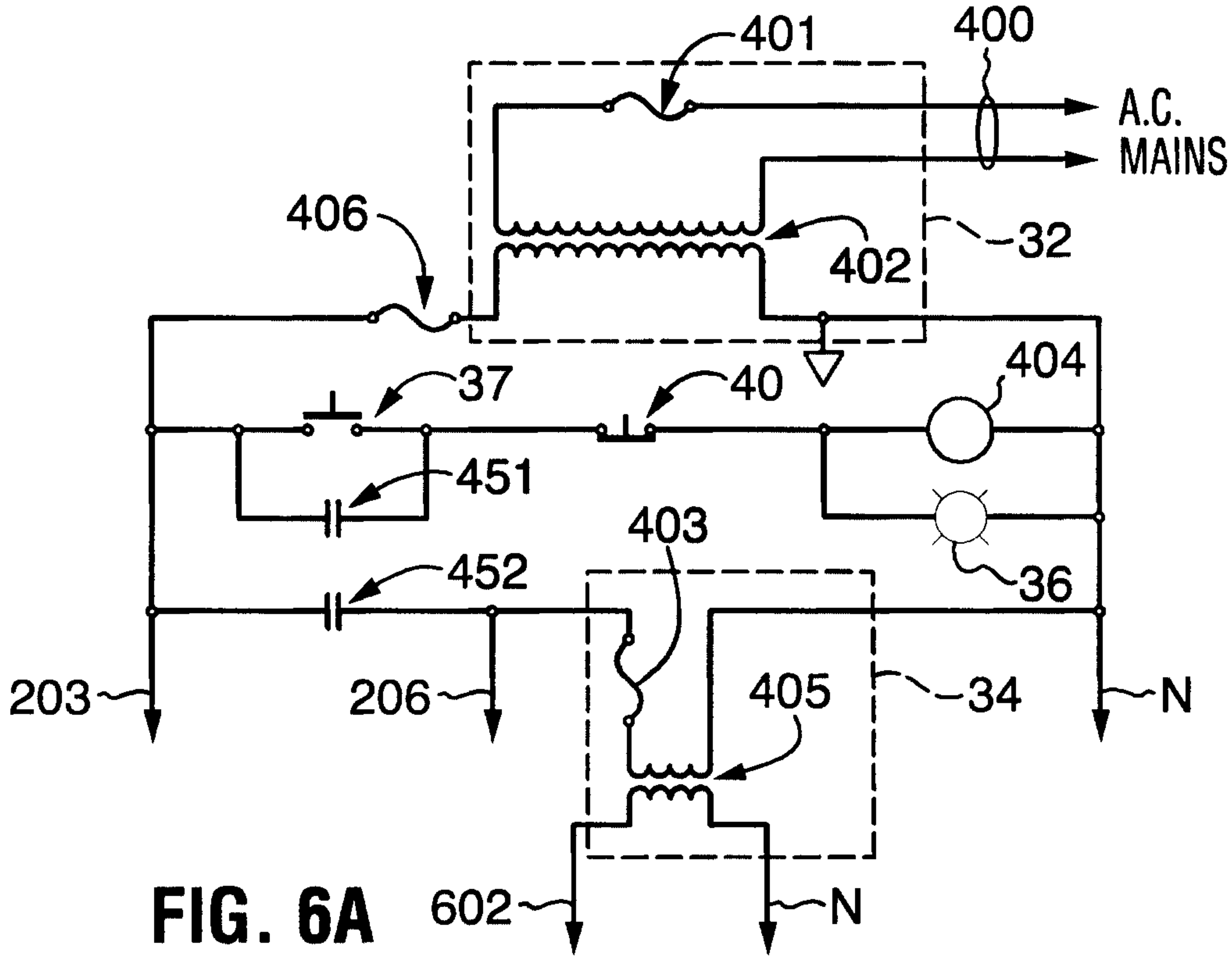

401
400
A.C.
MAINS
406
402
32
37
40
404
451
403
36
452
405
203
206
34
N
602
N

FIG. 6A

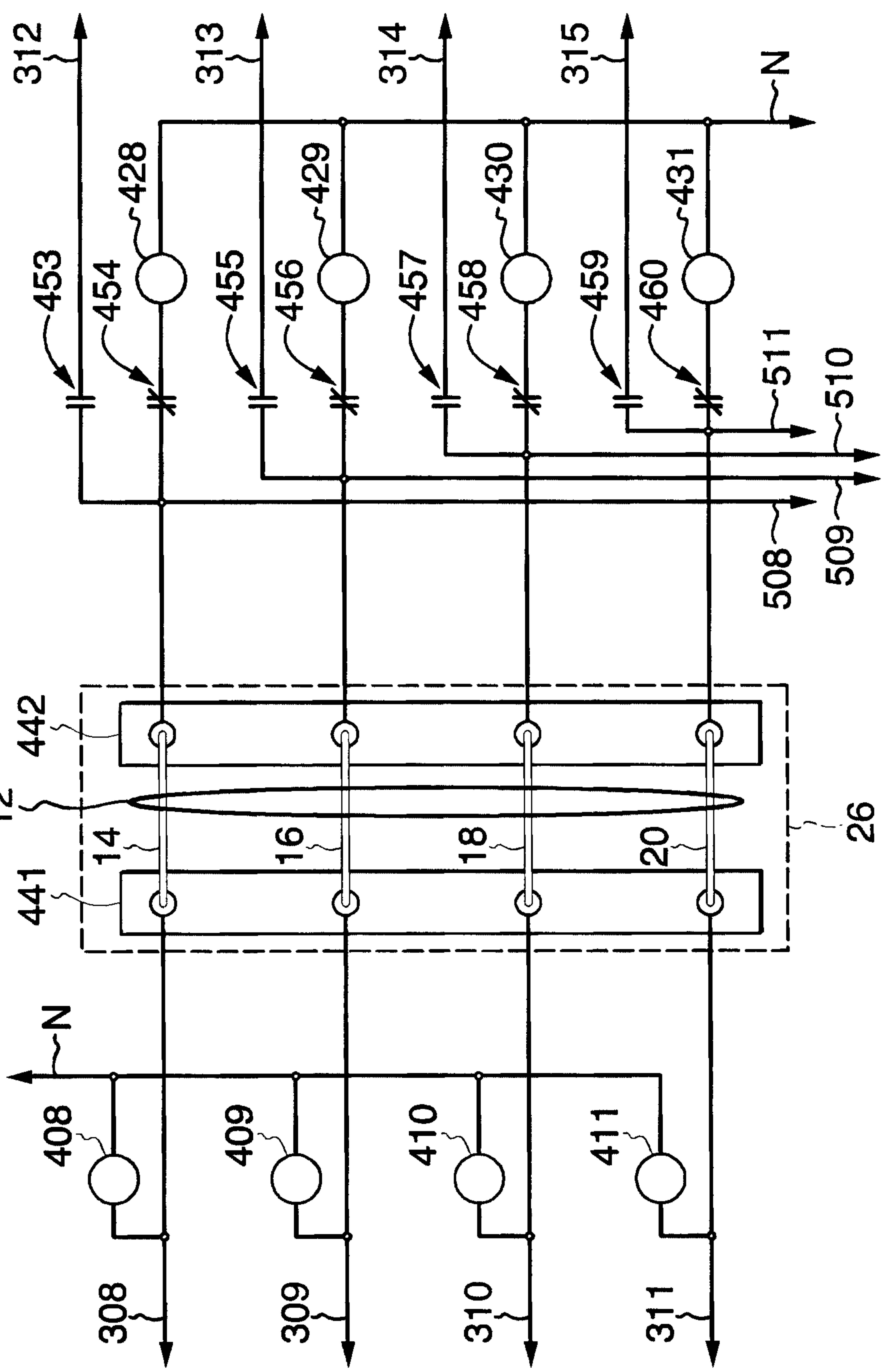
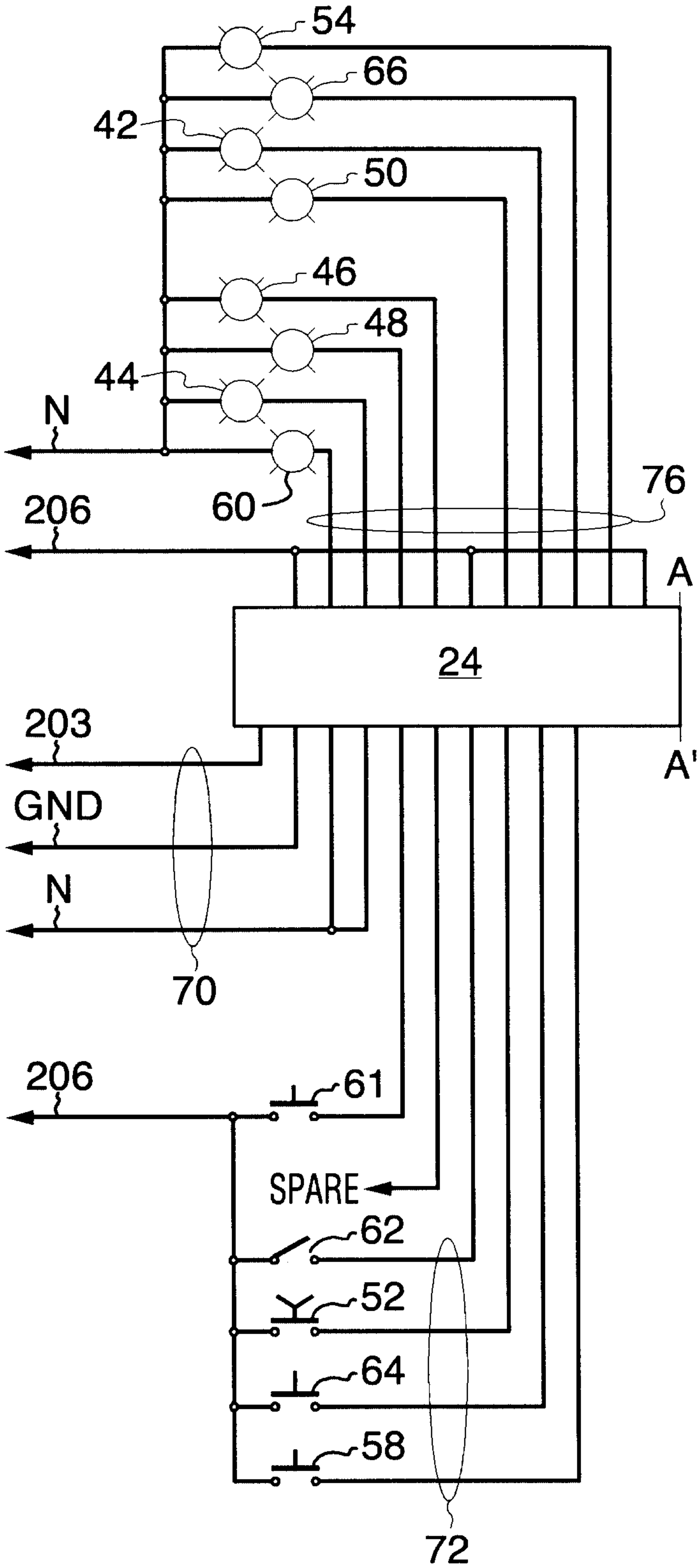

312
313
314
315
N
453
454
428
455
456
429
457
458
430
459
460
431
511
510
508
509
442
12
14
16
18
20
26
441
N
408
409
410
411
308
309
310
311

FIG. 6B



54
66
42
50
46
48
44
N
60
206
76
A
24
A'
203
GND
N
70
206
61
SPARE
62
52
64
58
72

FIG. 6C

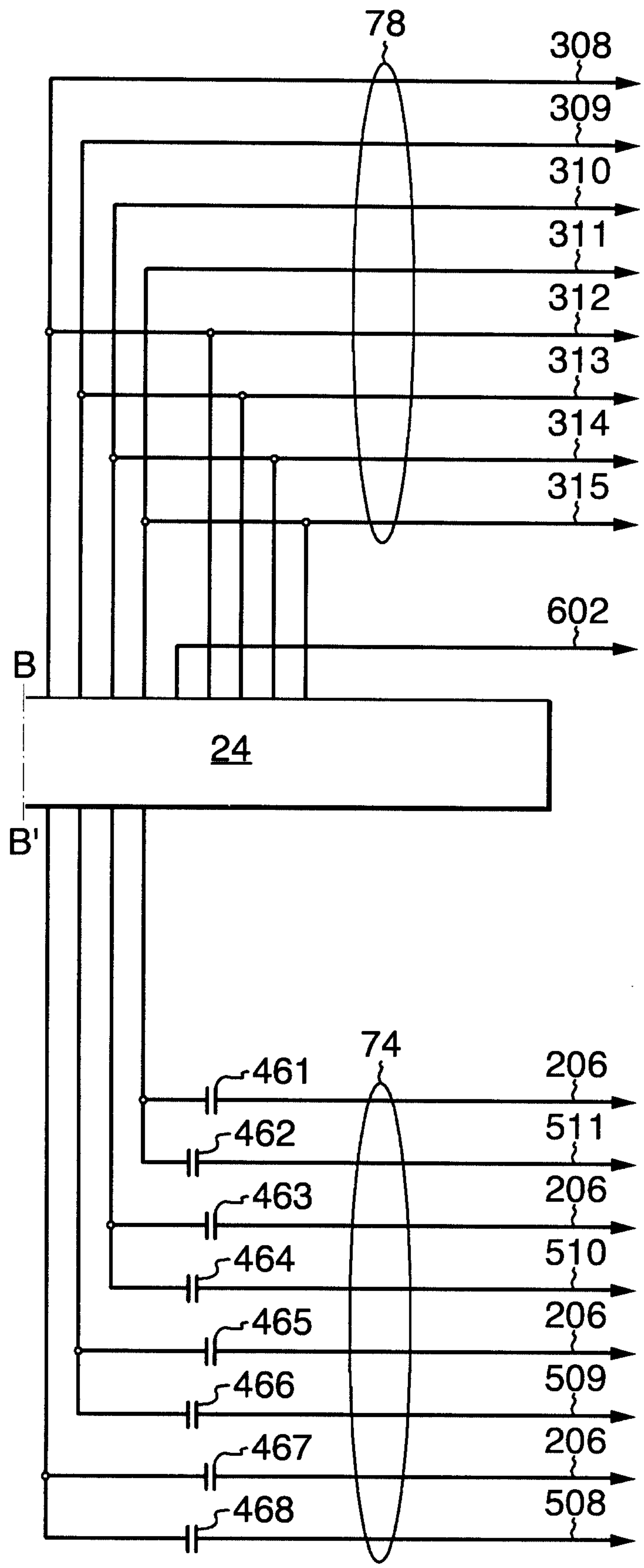
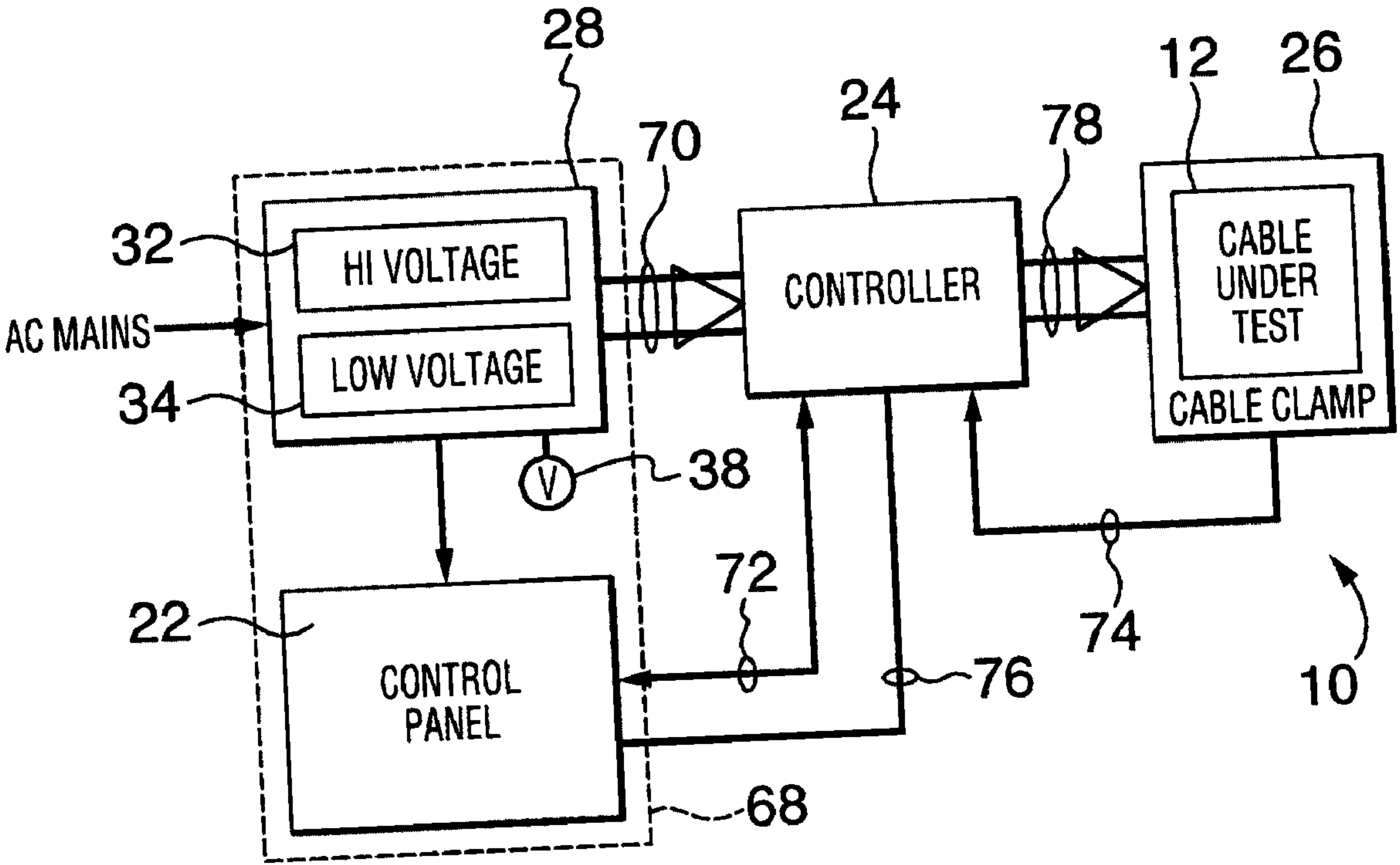

78
308
309
310
311
312
313
314
315
602
B
24
B'
74
461
206
462
511
463
206
464
510
465
206
466
509
467
206
468
508

FIG. 6D


28
70
24
78
12
26
32
HI VOLTAGE
CONTROLLER
CABLE UNDER TEST
AC MAINS
LOW VOLTAGE
34
CABLE CLAMP
V
38
72
74
22
CONTROL PANEL
76
10
68